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ERECTING 60-METER PRESTRESSED CONCRETE TRUSS IN ONE UNIT BY JACK LIFTING METHOD

- COMMUNIST CHINA -

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[Following is the translation of an article written by the Construction Technique Research Division, Institute of Building Science, Ministry of Building Construction, in Kung-ch'eng Chien-she, (Engineering Construction), Peiping, No. 5, 10 March 1960, pages 1-5.]

Recently, the Peiping No. 2 Construction Company, cooperating with related organizations in a certain engineering project, succeeded in employing the one unit jack lifting method in erecting a roof structure of 60-meter prestressed concrete truss. Valuable experiences have been gained in this construction. A brief discussion of this method is presented in the following.

I. Engineering Scope

The elevated structure of this engineering projec involves a span of 60 meters and depth of 64 meters; the elevation of the lower chord of the truss is 16.50 meters from the lower level. At the joint of the lower chord, there is a 5-ton multiple support crane runway and conveying facilities (Figure 1). The truss is an ornamental type of prestressed reinforced concrete arch-shape truss, as shown in Figure 2. Spacing of columns is 6.4 meters. The roof is 1.5 x 6.25 meter reinforced foam concrete ribbed panels. In order to decrease the dead load of the truss in jack lifting, the upper chord section is poured in two separate times.

The center height of the truss is 6.5 meters, formed of 19 pieces of precast units. The lower chord

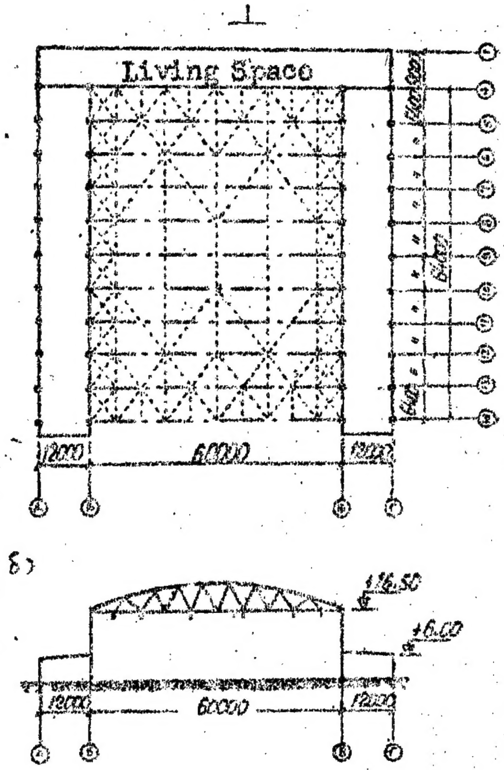


Figure 1 Machine Repair Shop
a – Plan and Level Support (Lower Chord)
б – Elevation and Vertical Support

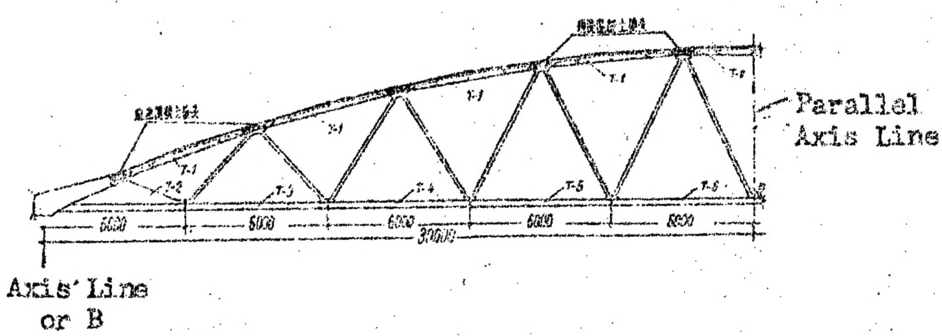


Figure 2
60m Prestressed Concrete Arch-Shape Truss

section is 28 x 55 centimeters, comprising 10 strands of Φ5-19R$^{y}_{y}$ = 11,000 kg/cm^2 high-strength steel wires. There are six types of precast units, all made of No. 500 concrete. T-1 is the upper chord of the double slope type channel section. T-2 is solid triangular end unit. T-3~T-6 is a triangular unit constructed with two diagonal members and one lower chord member. Each truss weighs about 66.72 tons.

In designing, consideration was given to the installation method of the great span structure. The pillars are made of geminated column channel section reinforced concrete structure; the clearance between the pillars is 70 centimeters (Figure 3). The width of tru at the ends os 60 centimeters, so there are 5 centimete clearance between the truss and the column channels.

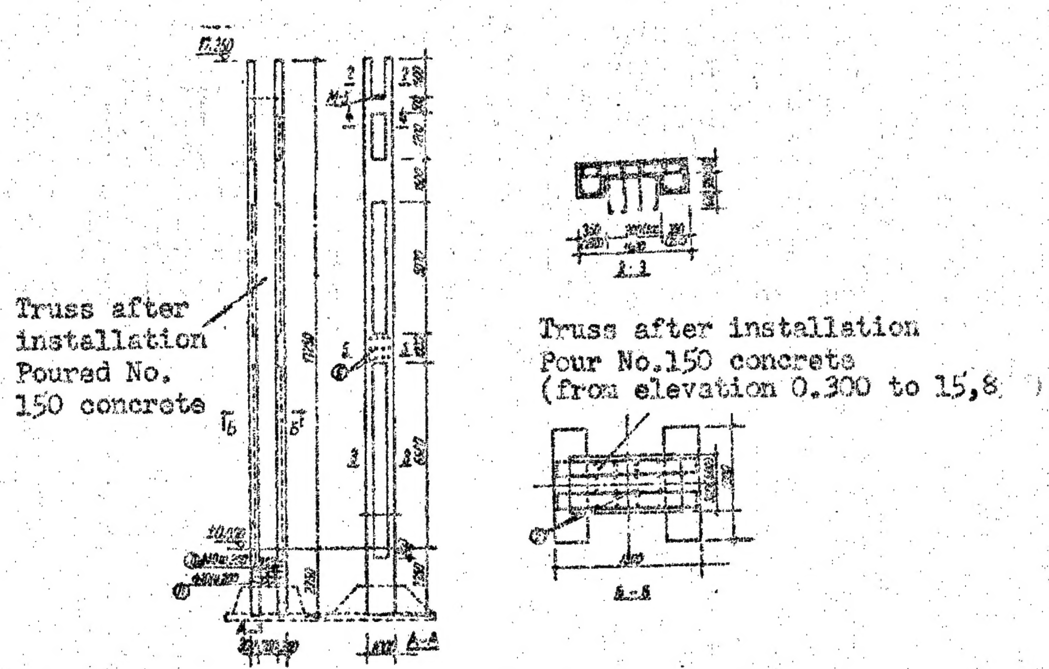


Figure 3 Geminated Columns

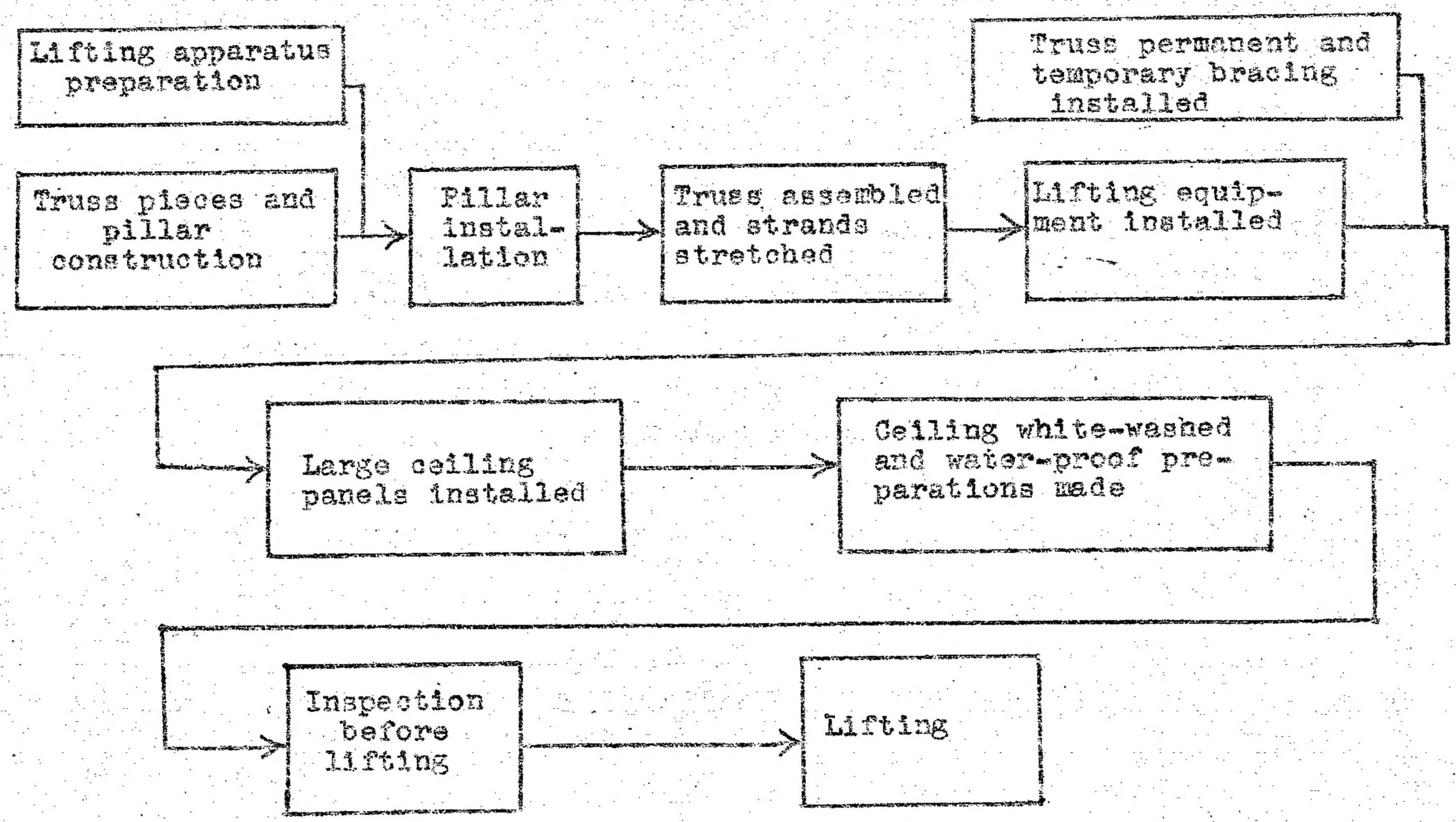
II. The Selection of Installation Solution

As the dead weight of the truss is more than 60 tons, and its center of gravity is higher than its supports, the conventional hang-lift erection method cannot be used. Also, because the unity of the whole truss is obtained after prestressing the ten high-strength steel wire strands in the lower chord, the rigidity is higher. Therefore, the truss must be assembled at the ground level, the strands stretched, the roof panels and the bracings all put into place so as to form a rigid and stable unit. Then, erect the whole unit to the designed position bay by bay.

The weight of each unit is as follows:

Truss dead weight (excluding the concrete poured later)	2 x 60 = 120 tons
Roofing	40 x 1.5 = 60 tons
Bracing & lifting tools	20 tons
	200 tons

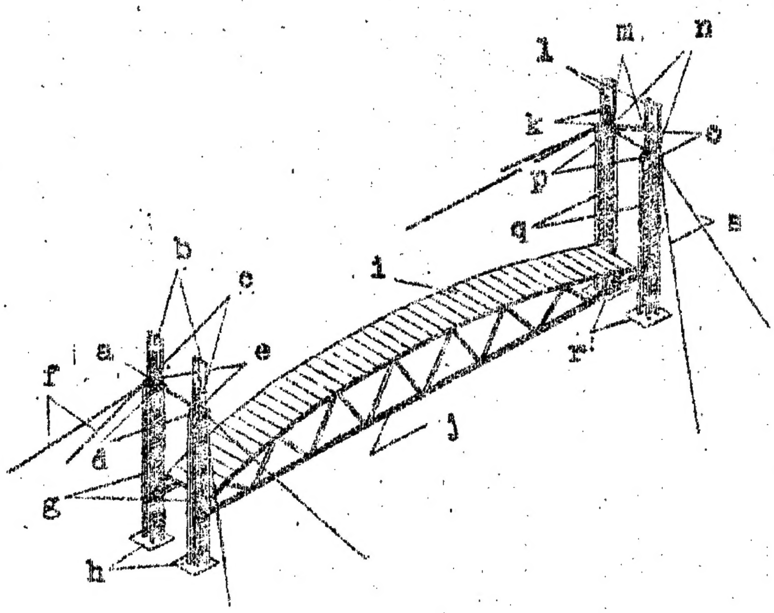
It is difficult to use the usual double hoisting gear and the multiple hoisting gear to erect such a large span and such a heavy structure; hence, the steel-strap jack lifting method is employed. In this method, a steel-strap oil pressure jack lifting machine is placed on the top of each geminated column, which are at the four corners of the roof truss unit. With these steel straps and jacks, the roof truss unit is raised to the designed position. The order of the principal construction steps are:



Principal Construction Steps

III. Lifting Truss Unit

The steel strap oil pressure hoisting apparatus i made by the supporting beam, the lower beam, the upper beam, oil pressure jack, steel straps, and steel pillars Besides, there is a platform for the workers to work on and there are the steel rod levers, wrenches, steel cabl which are used to lift the truss up step by step togethe with the steel straps (Figure 4). On the top of each column, there is set up the steel strap hoisting equipment (four sets in all). The wrench is set up on the ground.



a—Fixed Beam
b—Portal Frame
c—Hoisting Beam
d—Jacks
e—Beam Support
f—Steel Cables
g—Concrete Geminated columns
h—Foundation
i—Precast Large ceiling panels
j—61m Span Prestressed Concrete Truss

k—Steel Straps
l—Portal Frame
m—Hoisting Beam
n—Jacks
o—Fixed Beam
p—Beam Support
q—Concrete Geminated columns
r—Foundation
s—Steel Cables

Figure 4

Steel Strap Hoisting Apparatus

The four sets of steel strap hoisting equipment (not including the jacks) use 32 tons of steel materials, and the effective weight is 2.9 tons.

The steel strap section is 280 x 60 millimeters, formed by three pieces of 20 millimeter steel plates, Its length is 20 meters, divided into five sections, each of which is connected by a splice plate and a bolt, and the steel plates are joined together by countersunk rivets.

The jack is fixed on the lower beam, and on either end of the lower beam is installed a guide channel and a steel channel, which regulate the up and down movement of the upper beam.

The steel rod lever is fixed on the beam for the dismounting and installing of the steel strap.

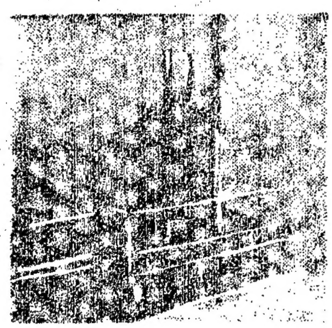


Figure 5

Steel strap oil pressure hoisting apparatus

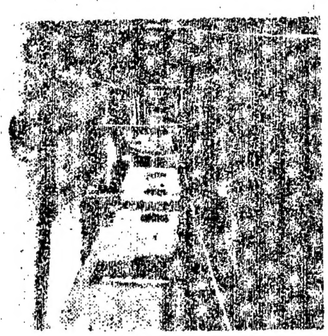


Figure 6

Steel strap

Technical Properties of Electric Strap Type Hoisting Machine

Item	Quantity	Properties Explaine
Weight lifted	4 steel straps	300t
Total weight of hoisting machine	4 steel straps	29t
300t jack	8 sets	Moving distance 30c
High pressure oil pump	2 sets	4.5 kilowatt each
Steel cable, 21Φ		
Wrench	4 sets	1~1.5t
Time for raising 20 cm		4 minutes

The moving distance of a 300-ton oil pressure jac is 30 centimeters. Owing to the consideration given to possible error in the structure of the concrete pillar, the truss and the steel strap, it is necessary to reserve a part of this moving distance (10 centimeters) for adjustment; thus, 20 centimeters are actually utilized. The diameter of the steel rod is 95 millimeters. In orde not to weaken the strength of the steel strap on account of the holes on it, the distance between two holes is set to be twice that of the effective moving distance of the jack, that is, 40 centimeters.

At the same time, the distance between the upper and lower holes on the beam is set to be three times that of the effective moving distance, that is, 60 centimeters. Accordingly, the hole distance on the beam is just one moving distance greater than the hole distance in the steel strap (20 centimeters), so in the lifting operation, the hole on the beam each time coincides with the hole on the steel strap.

It must be pointed out that the steel strap and the roof truss unit are moving along the vertical center line between the columns and the horizontal clearance of

the latter is very small (about three centimeters, steel strap 6 centimeter thick, width of channel hole 9 centimeters). Accordingly, there must be a very careful inspection of the possible errors of the various parts and to control them as far as possible, such as deviations in the column vertical center line, in truss length, position of the truss assembly, formation of the steel strap, height of the installation, and in the total length of the steel strap and the distance between holes. All these must be carefully inspected, put in the record and rectified as soon as mistakes are discovered to prevent the catching of steel strap and the beam or to avoid collision between the truss and the columns; thus, accidents will be prevented.

In lifting the truss unit, the error in controllin i.e., the difference of elevation along the distance between the columns, cannot be more than 10 millimeters, and as to the difference of elevation along the directior of the truss axis, the error cannot be more than 100 millimeters. A reading must be made of the movement at eac jack and a report is made by telephone connections so as to control the lifting speed whereby the rise of the truss unit will be steady, thus avoiding accidents to the various members.

Measures to stabilize the columns: (1) between th columns (6.4 meters in distance) erect an 8-meter-high 37-brick wall; (2) the tops of the two columns should be tied together by a tension tie (ϕ 25); (3) at the heigh of 13.50 meters on each column make a steel ring and a steel cable; (4) add another steel cable to each column at the support beam, as shown in Figure 7.

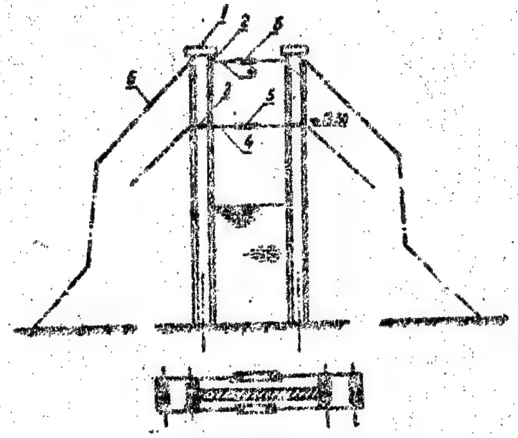


Figure 7

Support between the columns and the steel cables.
1. Lower steel beam; 2. support beam; 3. steel ring; 4. tension tie; 5. turn buckle; 6. steel cables.

For the stability of the two columns, two methods have been adopted in designing: (1) at every 200 centimeter interval, the columns are joined together by a 12x40x1020 millimeter steel plate and bolts. Following the rise of the truss unit, dismount the top iron plate and install the lower iron plate, to guarantee the stability of the two columns; (2) in order to save the above mentioned steel materials and to strengthen the rigidity of the columns (during the operation time), when the second truss unit is to be about lifted, the plates connecting the two columns should be removed and substituted by steel dowels and in the lifting process, iron rings should be used (in actual construction when the rings are not added, the columns still have enough stability).

After the truss unit has been lifted to a certain height, the steel dowels should be straightened and No. 200 concrete poured.

The lifting method and procedure (Figure 8):

First procedure--To begin with, put the steel bolt into the "a" hole on upper beam, and remove the steel bo[lt] from the "c" hole on the lower beam. Start (hand operate or power operate) the oil pressure jack so that the valv[e] gradually rises to 20 centimeters. At this time, the hole on the steel strap and the "d" hole on the lower beam coincide with one another, then put the steel bolt into the "d" hole to stabilize the truss unit.

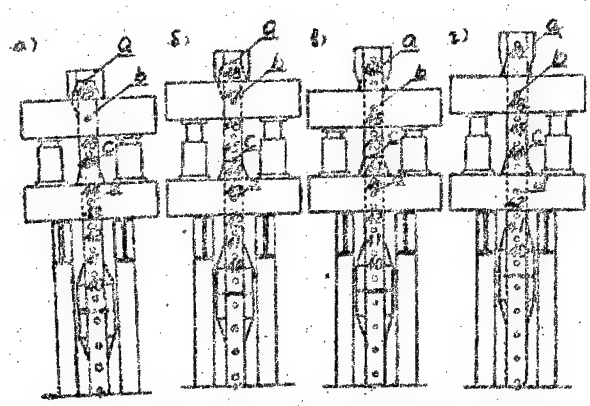


Figure 8 The construction procedure of strap type liquid hoisting apparatus.
a--half hole on the upper steel beam; b--the bolt hole on the upper steel beam; c--half hole on the lower stee[l] beam; d--the bolt hole on the lower steel beam; the st[eel] bolt. the bolt hole on the beam. the bolt hole on the strap.

a--the steel bolt put into the "a" hole, ready for lifting; 6--lifting to a certain distance, the steel bolt is inserted into the "c" hole; B--remove the steel bolt from "a" hole, the upper beam lowers with the jack; r--the steel bolt is inserted into the "b" hole and remove the steel bolt from the "c" hole, then proceed for the second lifting.

Second procedure--Remove the steel bolt from the upper beam, loosen the oil valve of the jack. At the same time, start the valve of the oil pump (300 ton oil pressure pump is a double action equipment), rendering the upper beam to lower with the valve, till "b" hole coincides with the hole on the steel strap again and insert the steel bolt, preparing for the second lifting.

Third procedure-- Remove the steel bolt from the lower beam, start the oil pump, rendering the valve rising to 20 centimeters. At this time, the hole on the steel strap coincides again with the "c" hole on the lower beam, and insert the steel bolt to stabilize the truss unit.

The above procedures are repeated in operation until the truss unit has risen to 4.0 meters, then use the lever hoisting equipment to remove a section of the steel strap. This operation is repeated until the truss unit has risen to a point 5 centimeters above the designed elevation, the precast reinforced concrete bearing block is placed on the top of the column and then the truss unit is settled on it.

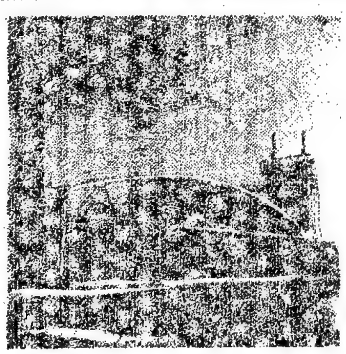
Before lifting, a careful inspection must be made of the functioning of the jacks, the position of the steel strap and the elevation of its topmost hole and its bottom hole, and the position of the truss unit. If any defect is discovered, rectification must be made before lifting starts. At the same time, during the lifting process, attention must be given to the movements of the steel strap and the truss unit to see whether there is any blocking on the way. Such measures will guarantee a steady and rapid rise of the truss unit.

When the wind is blowing at the 3-4 grade velocity the lifting operation should be stopped. At either end of the truss unit, steps must be taken to prevent vibration. Because the hook of the truss unit and the lifting beam and steel strap are joined together (by steel bolts), the truss unit will vibrate when the wind blows against it. Care must be taken to prevent the steel strap from breaking.

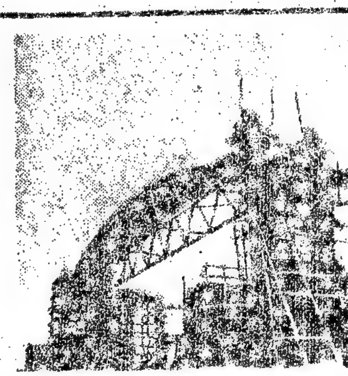
The installation elevation of the truss unit is 16.50 meters, so the truss unit must make 84 lifting moves. The whole operation was done by two shifts of workers, with 34 men per shift. The lifting of the first truss unit was done by manual operation. Because the workers were not skillful, the operation was completed in five days; the average daily lifting was 3.30 meters, and the greatest efficiency in one day was 4.4 meters. The principal reasons that affected the speed of lifting were: manual operation; the 300-ton jack used was of too great a tonnage, 10 times greater than what was required. In rising through the same 20 centimeter lifting distanc the 300-ton jack, as compared to a 100~200 ton jack, uses several times greater amounts of oil. Accordingly, it requires more time to complete one lifting distance, about 24~30 minutes, whereas a 200-ton jack requires only 12 minutes.

A Table of Lifting Time Recorded

Truss Unit Number	Lifting Time	Number of Workers	Explanatio
1st unit	72 hours	34 men	Hand operat
2nd unit	26 hours	17 men	Power oil pum
3rd unit	23 hours	17 men	Power oil pum
4th unit	28 hours	17 men	Power oil pum
5th unit	12.5 hours	17 men	Power oil pum



Truss Unit Lifted from Ground



Lifting Completed

Figure 9

To increase the speed of lifting, save labor power and to reduce the workers' physical labor, in lifting the second unit, the repair plant cooperated and put great efforts in establishing two 4.5 kilowatt high-pressure oil pumps. Since then only 4 minutes were required to complete one lifting distance and 12.5~28 hours were required to complete the lifting of one unit. The efficiency rate was raised 1.57~4.76 times. Labor was reduced from 34 men to 17, attaining a 50% saving.

When hand operated oil pumps are used, if all the pumps are operated in the same direction, the slower the motion the greater is column vibration. Accordingly, if the pumps are operated in opposite directions, and the speed increased, the columns become relatively steady. After the power operated oil pumps were used, the problem of vibrating columns was solved.

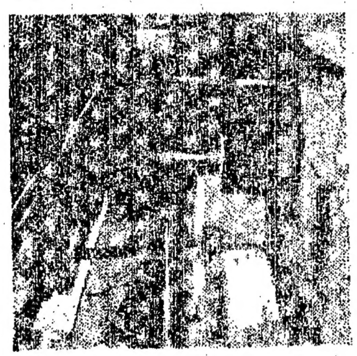


Figure 10
Concrete bearing block set on top of a column

In installing the first truss unit, the steel strap equipment used a lace strap crane and its lever was extended to 29 meters. Afterward, the crane was transferred to some other place. As a result, when the first truss unit was completed, the dismounting and installing of the steel strap lifting equipment (on top of the columns in the second truss unit) were done by the steel bar lever of the hoisting apparatus. First, use the steel bar lever to dismount the upper beam, the two jacks and the lower beam, then use another fork-shape lever to dismount the steel bar lever and the supporting beam. In installing, first, set up the fork-shape lever on the scaffolding at the column top. With this lever, the supporting beam and the steel bar lever are set up. Then, by the use of steel bar lever, the lower beam, jacks, upper beam and steel straps are installed. Such a procedure cycle requires only 3-4 days (one shift system).

While installing the hoisting equipment, a wooden lever is used to install the roof panels. From the installing of the hoisting equipment to the completion of lifting a truss unit, the operation requires only 5 days. If a lace strap crane is used to assist the installation of the hoisting equipment (the entire installation) and the roof panels, the installation time for a truss unit can be reduced to three days.

The roof panels of the two remaining truss units were later installed by a tower crane, which was used to install the living space structure.

IV. Conclusion

The application of the lifting method to install such a great span of concrete truss is not only a stable and reliable method, but also a combination of native and foreign methods and an excellent simple mechanized method that will give better results. This method has opened a new technical path for the future installation of great span structures and at the same time has promoted the utilization and expansion of great span structures in production.

1. The merits of the lifting method:

(a) The lifting power is greater than the existing hoisting equipment. The structure is simple. Any construction unit can make it.

(b) It consumes very little steel material, needs little electric power and little labor power and does not require skilled hoisting workers. Any carpenter and frame worker, after one unit operation, can operate it easily.

(c) Every part of the structure in the truss unit can be assembled on the ground; painting and white washing are also done on the ground. A great part of the work that is supposed to be done at heights is now done on the ground. It guarantees the structure's rigidity, quality, working safety and rapid installation.

2. After the electric power high pressure oil pump was substituted for manual operation, the method manifested superior quality. But, from the analysis of the time used in lifting, it shows that there still is a potentiality to be developed. The actual lifting time is only 7 hours, while the rest of the time is consumed in dismounting steel straps (dismounting one section after every 4 meters), changing steel cables (elevation

13.5 meters) and other activities to prevent accidents. The non-productive time occupies a great proportion. According to the experiences gained from this construction if the quality of the steel strap installation can be raised and the 13.5 meter elevation steel cable stabilization method can be improved, the lifting time can be reduced by one-third.

The application of the 300-ton oil pressure jack though the valve returns to its original position by the oil pressure (suitable for jack lifting), can attain a lifting distance of only 30 centimeters. The jack itself is not accurately made and has a great dead load, so it is not an ideal jack for lifting purpose. If a 100~150 ton special jack is used, the lifting distance may reach 40, 80, or even 120 centimeters. And by using the present steel straps, the lifting speed can be reduce to half.

3. According to observations of this lifting operation, the speed of lifting the truss unit by hand operation is one centimeter per minute and by electric power oil pump operation is seven centimeters per minute.

Though there is a 3~6 centimeter error between the total length of the hook on the two ends of the truss and the span on the top of the column, the top of the column, which is a free end, can be adjusted automatically to the gradual rising of the truss to meet practical demands. It must be pointed out that the accuracy of installing the elevation for the lifting beams is very important, because the accurate elevation has an important bearing on the problem of whether the four jacks can operate at the same speed simultaneously and whether the steel bolt can be inserted simultaneously. If the elevation is inaccurately installed, it will affect the simultaneous rising and simultaneous insertion, which will bring abou delays.

4. The diameter of the hole on the steel strap is 106 millimeters, while the diameter of the steel bolt is 95 millimeters. The contact area and the numerical valu of the calculation have a great difference. The pressu on the hole wall is too concentrated, damaging the edge of every hole. According to experiences gained in this construction, the measurement for the making of the steel straps must be strengthened, welding contacts must be changed, the column top elevation, the elevation of the assembled truss and other related measurements must be carefully inspected and rectified. The holes on the

steel strap could be changed into an oblong shape simila to the round shape of the steel bolt to facilitate insertion. It is not advisable to reduce the diameter of the steel bolt as a method to adjust the various errors.

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